XXVII. *The Description of Two new Micrometers.* *By* *Mr.* Ramfden, *Optician*; *communicated by* Jofeph Banks, *Efq. P. R. S.*

WHEN I offer the defcription of a new micrometer to the learned members of the Royal Society, I do not flatter myfelf that mere novelty will entitle it to their patronage. Senfible how much the theory of aftronomy is limited by the imperfection of inftruments, I always incline to improve rather than invent, except when repeated examinations convince me, that the imperfections arife from defect in principle as well as in the conftruction.

In confidering micrometers, when an obferver finds, that with the micrometer, which depends on moveable parallel wires, he cannot meafure any diameter of a planet, except that which is at right angles to the direction of its apparent motion, he cannot withhold his preference to that conftruction which meafures the angle by the feparation of the images. It appeared therefore

to

to me a matter of fome importance, to inveftigate the caufes of the uncertainty which has been found in the obfervations made with the micrometer with a divided object-glafs. The refult of my examination convinced me, that were it poffible to execute the conftruction of that micrometer, with the degree of accuracy required, it muft ftill be fubject to inaccuracy from its principle.

By the pofition of the micrometer every error of its glafs is magnified by the telefcope; and if each furface of the micrometer glafs has not, in every part, precifely the fame radius (which opticians muft allow to be exceedingly difficult) there will be a confiderable error in the angle to be meafured, and the eye applied to the different parts of the pencil will, without moving the micrometer, fee the images of the object in the telefcope fluctuating, fometimes appearing to overlap, and fometimes to feparate from each other.

But fuppofing the glafs itfelf to be perfect in its fubftance and in its curvature, there will yet remain imperfections which arife from its principle. A micrometer glafs applied to a telefcope caufes a very confiderable abberration. If the focus of the glafs is pofitive, the extreme aberration will be within the geometrical focus; if negative, it will be beyond it: and the aberration not only

affects

affects the diftinctnefs of the image, but alfo the angle meafured by the micrometer.

At the time I took up this fubject, the divided object-glafs micrometer was the only one which meafured angles by the feparation of two images. Since that time, a very ingenious application of the prifm to this purpofe has been invented by the rev. Dr. MASKELYNE, Aftronomer Royal; and although experience has not yet afcertained the extent of its merit, it will always deferve great confideration from its ingenuity; but the more I confidered the fubject, I became more fully convinced, that the principle of reflection applied to micrometers would have great advantages over thofe hitherto conftructed on the principle of refraction; and the catoptric micrometer I have the honour to defcribe, befides the advantage it derives from the principle of reflection, of not being difturbed by the heterogeniety of light, avoids every defect of other micrometers, and can have no aberration, nor any defect which arifes from the imperfection of materials, or of execution, as the extreme fimplicity of its conftruction requires no additional mirrors or glaffes to thofe required for the telefcope: and the feparation of the image being effected by the inclination of the two fpecula, and not depending on the focus of any lens or mir-

ror,

ror, any alteration in the eye of an obferver cannot affect the angle meafured.

It has, peculiar to itfelf, the advantages of an adjuft-ment to make the images coincide in a direction perpen-dicular to that of their motion; and alfo of meafuring the diameter of a planet on both fides the zero, which will appear no inconfiderable advantage to obfervers who know how much eafier it is to afcertain the contact of the external edges of two images than their perfect coin-cidence.   A fhort explanation of the annexed drawings will make the conftruction and the properties of this mi-crometer obvious.

I divided the fmall fpeculum of a reflecting telefcope, of CASSEGRAIN's conftruction, into two equal parts, by a plane acrofs its center; and by inclining the halves of the fpeculum to each other on an axis at right angles to the plane that feparated them, I obtained two diftinct images. The fatisfaction I received on the firft trial was checked by the apparent impoffibility of reducing this principle to practice.   The angular feparation of the two images in this cafe being half the angular inclination of the two fpecula, it required an index of an unmanageable length, to allow the quantity of one fecond of a degree to be-come vifible.   Some time afterwards, on revifing the principle, I confidered, that if both the halves of the mir-

ror

ror turned on their center of curvature, there could be no alteration in their relative inclination to each other from their motion on this center; and that any extent of ſcale might be obtained, by fixing the center of motion at a proportional diſtance from the common center of curvature. This will be better underſtood from the annexed drawing.

A (fig. 1.) repreſents the ſmall ſpeculum divided into two equal parts; one of which is fixed on the end of the arm B; the other end of the arm is fixed on a ſteel axis x, which croſſes the end of the teleſcope c. The other half of the mirror A is fixed on the arm D, which arm at the other end terminates in a ſocket y, that turns on the axis, x; both arms are prevented bending by the braces *a a*. G repreſents a double ſcrew, having one part *e* cut into double the number of threads in an inch to that of the part *g*: the part *e* having 100 threads in one inch, and the part *g* 50 only. The ſcrew *e* works in a nut F in the ſide of the teleſcope, while the part *g* turns in a nut H, which is attached to the arm B; the ends of the arms B and D, to which the mirrors are fixed, are ſeparated from each other by the point of the double ſcrew preſſing againſt the ſtud *b*, fixed to the arm D, and turning in the nut H on the arm B. The two arms B and D are preſſed againſt the direction of the double ſcrew *eg* by

K k k 2 a ſpiral

a fpiral fpring within the part *n*, by which means all fhake or play in the nut H, on which the meafure depends, is intirely prevented.

From the difference of the threads on the fcrew at *e* and *g* it is evident, that the progreffive motion of the fcrew through the nut will be half the diftance of the feparation of the two halves of the mirror, and confequently the half mirrors will be moved equally in contrary directions from the axis of the telefcope c.

The wheel v fixed on the end of the double fcrew has its circumference divided into 100 equal parts, and numbered at every fifth divifion with 5, 10, &c. to 100, and the index I fhews the motion of the fcrew with the wheel round its axis, while the number of revolutions of the fcrew is fhewn by the divifions on the fame index. The fteel fcrew R may be turned by the key s, and ferves to incline the fmall mirror at right angles to the direction of its motion. By turning the finger head T (fig. 2.) the eye tube P is brought nearer or farther from the fmall mirror, to adjuft the telefcope to diftinct vifion; and the telefcope itfelf hath a motion round its axis for the conveniency of meafuring the diameter of a planet in any direction. The inclination of the diameter meafured with the horizon is fhewn in degrees and minutes by a level and vernier on a graduated circle, at the breech of the telefcope.

The

The method of adjufting and ufing the catoptric mi-
crometer is too obvious to require any explanation: it is
only neceffary to obferve that, befides the table for re-
ducing the revolutions and parts of the fcrew to minutes,
feconds, &c. it may require a table for correcting a very
fmall error which arifes from the excentric motion of the
half mirrors. By this motion their centers of curvature
will (when the angle to be meafured is large) approach a
little towards the large mirror; the equation for this pur-
pofe in fmall angles is infenfible, but when angles to be
meafured exceed ten minutes, it fhould not be neglected.
Or, the angle meafured may be corrected by diminifhing
it in the proportion the verfed fine of the angle mea-
fured, fuppofing the excentricity radius, bears to the focal
length of the fmall mirror.

The telefcope to which the catoptric micrometer is
applied is of the CASSEGRAIN conftruction. The great
fpeculum is about twenty-two inches focus, and bears an
aperture of $5\frac{5}{10}$ inches, which is conderably larger than
thofe of the fame focal length are generally made: in-
deed, the apparent utility of this micrometer makes me
wifh to fee the reflecting telefcope meet with further
improvements. I believe it would more tend to the ad-
vancement of the art of working mirrors, if writers on
this fubject, inftead of giving us their methods of working

ima-

imaginary parabolas, would demonftrate the properties
of curves for mirrors which, placed in a telefcope, will
fhew images of objects perfectly free from aberration;
or, what will yet be more ufeful in practice, of what
forms fpecula might be made, that the aberration caufed
by one mirror may be corrected by that of the other. If
mathematicians affume *data* which really exift, they muft
fee, that when the two fpecula of a reflecting telefcope
are parabolas, they caufe a very confiderable aberration,
which is negative, that is to fay, the focus of the extreme
rays is longer than thofe of the middle ones. If the large
fpeculum is a parabola, the fmall one ought to be an el-
lipfe; but when the fmall fpeculum is fpherical, which
is generally the cafe in practice, if concave, the figure of
the large fpeculum ought to be an hyperbola; if convex,
the large fpeculum ought to be an ellipfe, to free the te-
lefcope from aberration.

This will be eafier underftood by attending to the po-
fitions of the firft and fecond images; when a curve is of
fuch form that lines drawn from each image, and meet-
ing in any part of the curve, make equal angles with the
tangent to the curve at that point, it is evident, that fuch
curve will be free from aberration.

This is the property of a circle when the radiant
and image are in the fame place; but when they recede

                                                    from

from each other, of an ellipfe, of fuch form that the radiant and image are in the two *foci*, till one diftance becoming infinite the ellipfe changes into a parabola, and to an hyperbola when the focus is negative; that is to fay, when reflected rays diverge, and the focus is on the oppofite fide of the mirror.

Thefe principles made me prefer CASSEGRAIN's con- ftruction of the reflecting telefcope to either the Grego- rian or Newtonian. In the former, errors caufed by one fpeculum are diminifhed by thofe in the other.

From a property of the reflecting telefcope (which has not been attended to) that the apertures of the two fpecula are to each other very nearly in the proportion of their focal lengths, it follows, that their aberrations will be to each other in the fame proportion, and thefe aber- rations are in the fame direction, if the two fpecula are both concave; or in contrary directions, if one fpeculum is concave, and the other convex.

In the Gregorian conftruction, both fpecula being con- cave, the aberration at the fecond image will be the fum of the aberrations of the two mirrors; but in the CASSE- GRAIN conftruction, one mirror being concave, and the other convex, the aberration at the fecond image will be the difference between their aberrations. By affuming fuch proportions for the *foci* of the fpecula as are gene-

rally ufed in the reflecting telefcope, which is about as 1 to 4, the aberration in the CASSEGRAIN conftruction will be to that in the GREGORIAN as 3 to 5.

I have mentioned thefe circumftances in hopes of re-commending the demonftration of curves fuited to the purpofes of optics to the attention of mathematicians, which would be of great ufe to artifts.

I fhall conclude this paper with the defcription of a new micrometer fuited to the principle of refraction; being fenfible that both principles have their peculiar advan-tages   Though the former part of this paper proves my partiality to the principle of reflection applied to micro-meters, yet the very favourable opinion I have of the re-fracting telefcope made me attentively confider fome means of applying a micrometer to it, which might obviate the errors complained of in the former part of this paper.

The application of any lens or medium between the ob-ject glafs and its focus muft inevitably deftroy the diftinct-nefs of the image; I therefore have employed for the mi-crometer glafs one of the eye glaffes requifite in the com-mon conftruction of the telefcope; but if it fhould be found neceffary to apply an additional eye glafs for the conve-niency of enlarging the fcale, I am able thereby to cor-

4   rect

rect both the colours and spherical aberration of the first eye glafs.

This micrometer is applied to the erect eye tube of a refracting telefcope, and is placed in the conjugate focus of the firft eye glafs: hence arifes its great fuperiority to the object glafs micrometer. It has been before obferved, that if a micrometer is applied at the object glafs, the imperfections of its glafs are magnified by the whole power of the telefcope; but in *this* pofition, the image being confiderably magnified before it comes to the micrometer, any imperfection in its glafs will be magnified only by the remaining eye glaffes, which in any telefcope feldom exceeds five or fix times.

By this pofition the fize of the micrometer glafs will not be the $\frac{1}{100}$th part of the area which would be required if it was placed at the object glafs; and, notwithstanding this great difproportion of fize, which is of great moment to the practical optician, the fame extent of fcale is preferved, and the images are uniformly bright in every part of the field of the telefcope.

Fig. 4th, reprefents the glaffes of a refracting telefcope; *xy* the principal pencil of rays from the object glafs o; *tt* and *uu* the axis of two oblique pencils; *a* the firft eye glafs; *m* its conjugate focus, or the place of the micrometer; *b* the fecond eye glafs, *c* the third, and *d* the

fourth, or that which is neareft the eye.   Let *p* be the
diameter of the objeɕ glafs, *e* the diameter of a pencil at
m, and *f* the diameter of the pencil at the eye; it is evi-
dent, that the axis of the pencils from every part of the
image will crofs each other at the point *m*, and *e*, the
width of the micrometer glafs, is to *p* the diameter of the
objeɕ glafs as *m a* is to *g o*, which is the proportion of
the magnifying power at the point *m*, and the error
caufed by an imperfeɕion in the micrometer glafs placed
at *m* will be to the error, had the micrometer been at o,
as *m* is to *p*.

Fig. 3d, reprefents the micrometer; A a convex or con-
cave lens divided into two equal parts by a plane acrofs
its center; one of thefe femi-lenfes is fixed in a frame B,
and the other in the frame E, which two frames flide on
a plate H, and are preffed againft it by thin plates *aa:* the
frames B and E are moved in contrary direɕions by turn-
ing the button D; L is a fcale of equal parts on the frame
B; it is numbered from each end towards the middle
with 10, 20, &c.   There are two verniers on the frame
E, one at M, and the other at N, for the conveniency of
meafuring the diameter of a planet, &c. on both fides
the zero.   The firft divifion on both thefe verniers coin-
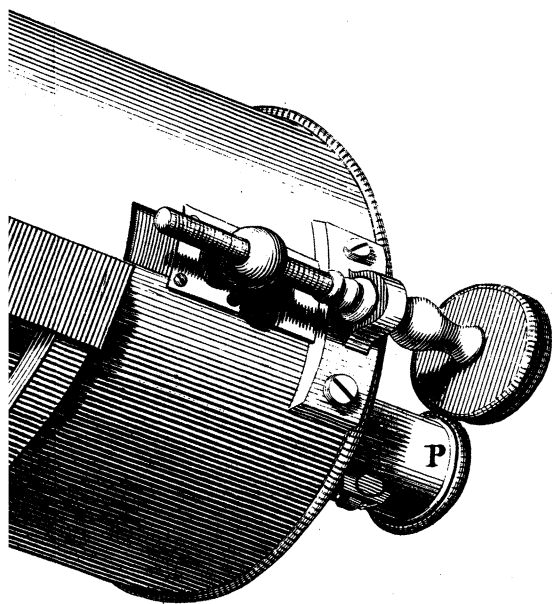cides at the fame time with the two zero's on the fcale L,
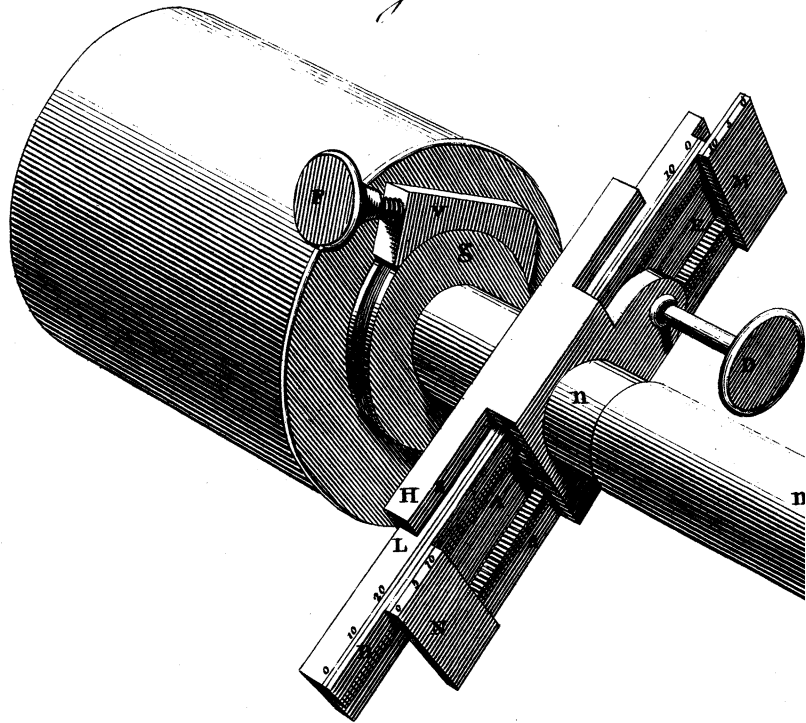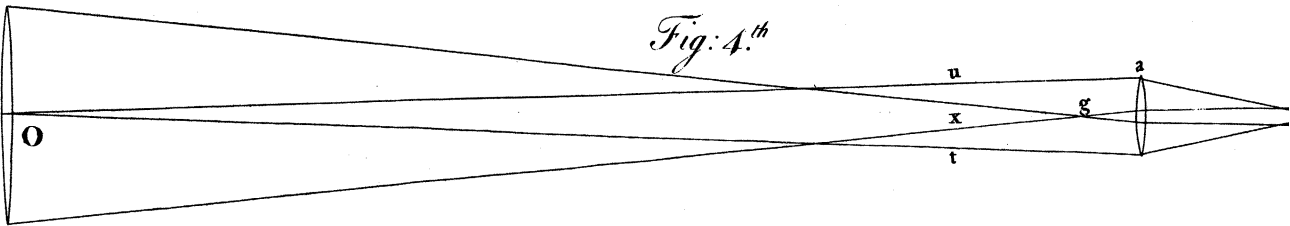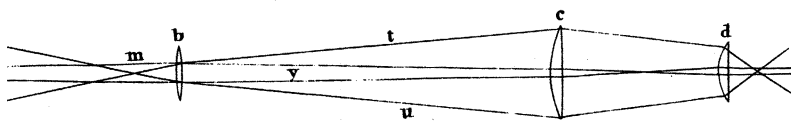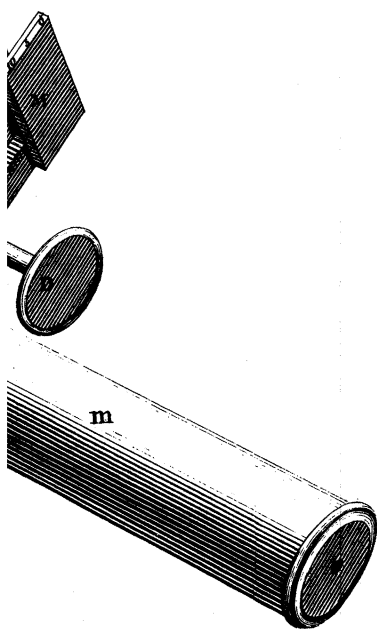
and,

Fig: 1.

C

Fig:2.
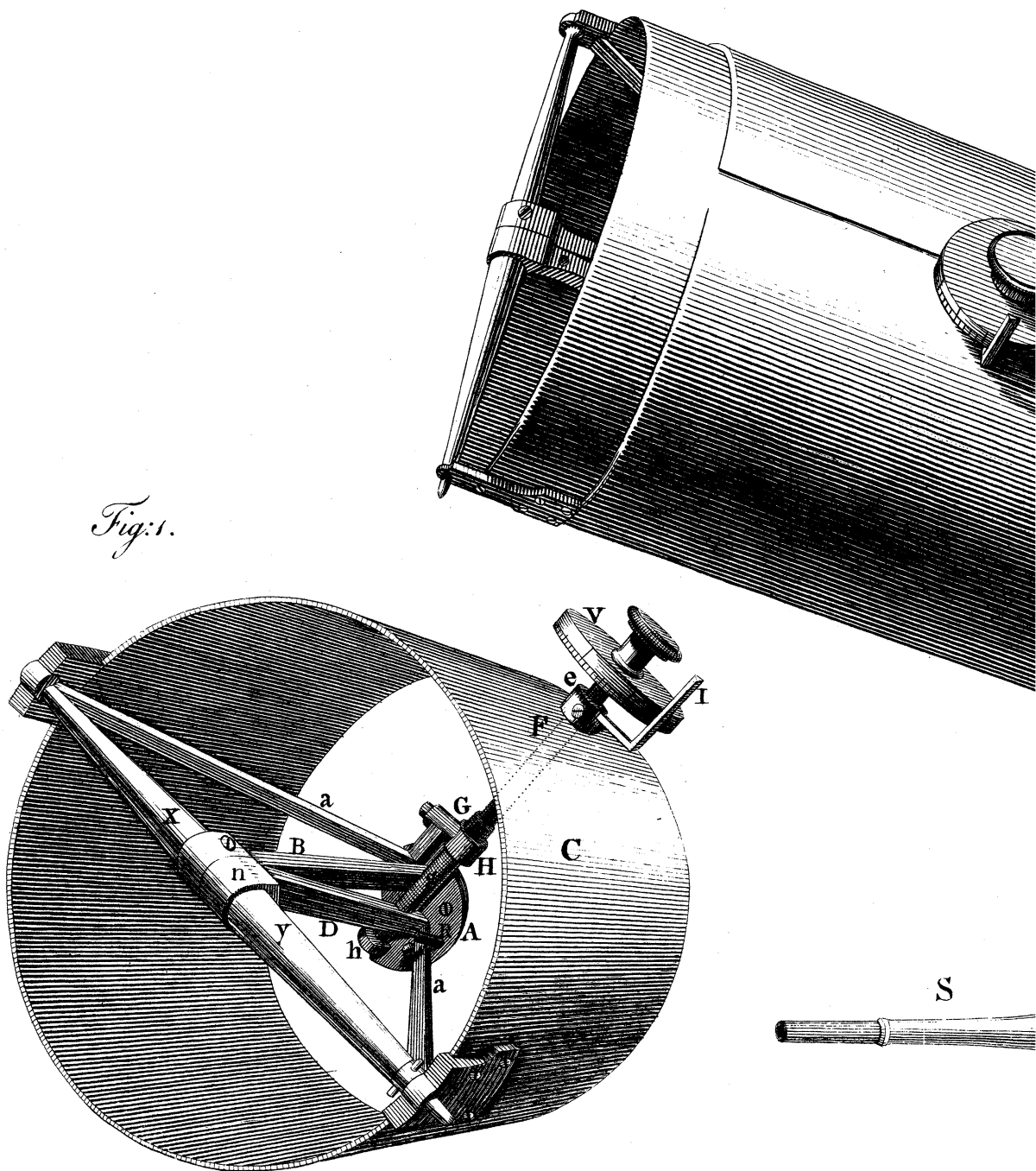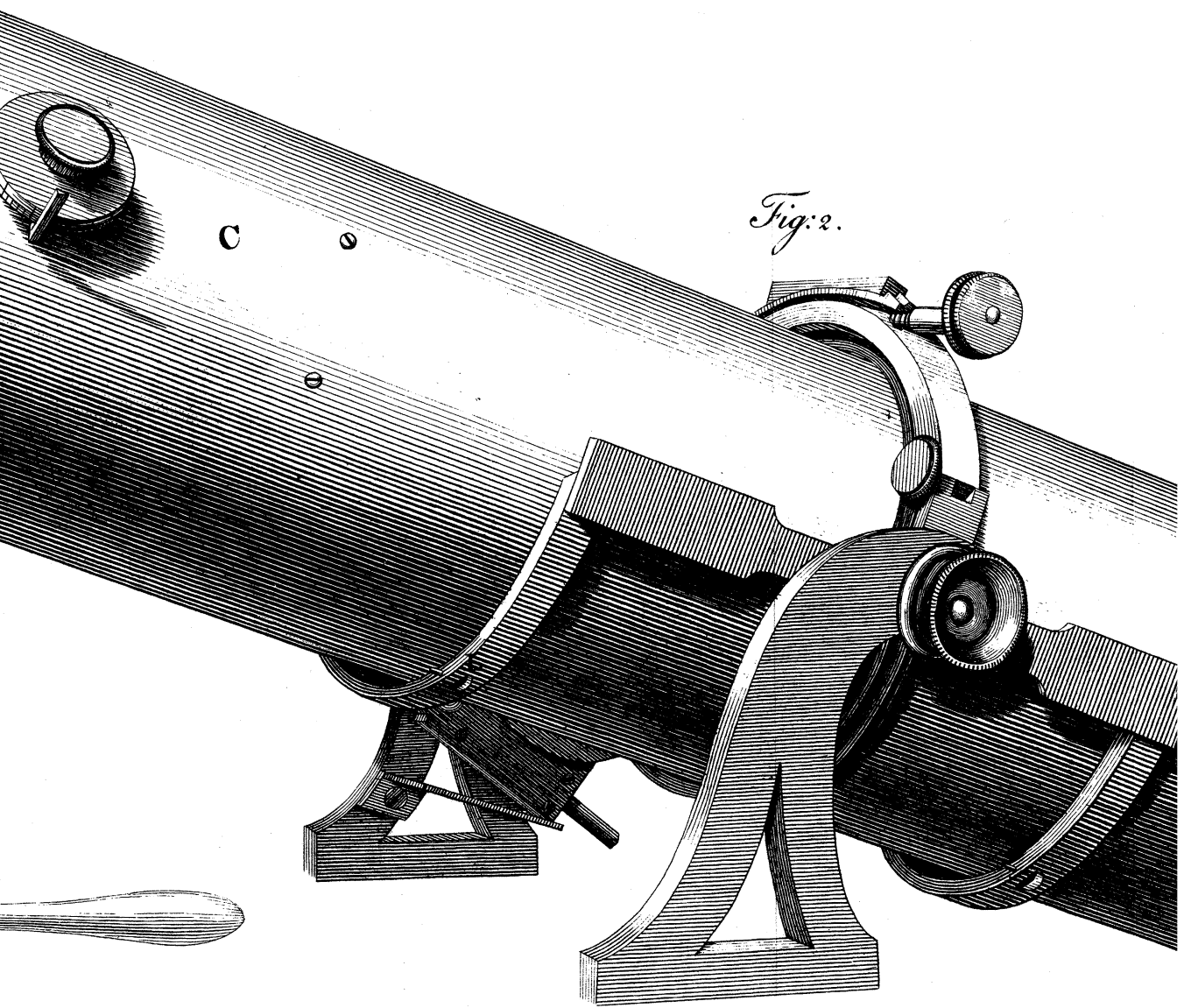
Fig: 3.ᵈ

Fig: 4.ᵗʰ

and, if the frame is moved towards the right, the relative motion of the two frames is fhewn on the fcale L by the vernier M; but if the frame B be moved towards the left, the relative motion is fhewn by the vernier N.

This micrometer has a motion round the axis of vifion, for the conveniency of meafuring the diameter of a planet, &c. in any direction, by turning an endlefs fcrew F, and the inclination of the diameter meafured with the horizon is fhewn on the circle *g* by a vernier on the plate V. The telefcope may be adjufted to diftinct vifion by means of an adjufting fcrew, which moves the whole eye tube with the micrometer nearer or farther from the object glafs, as telefcopes are generally made; or the fame effect may be produced in a better manner, without moving the micrometer, by fliding the part of the eye tube *m* on the part *n*, by help of a fcrew or pinion. The micrometer is made to take off occafionally from the eye tube, that the telefcope may be ufed without it.
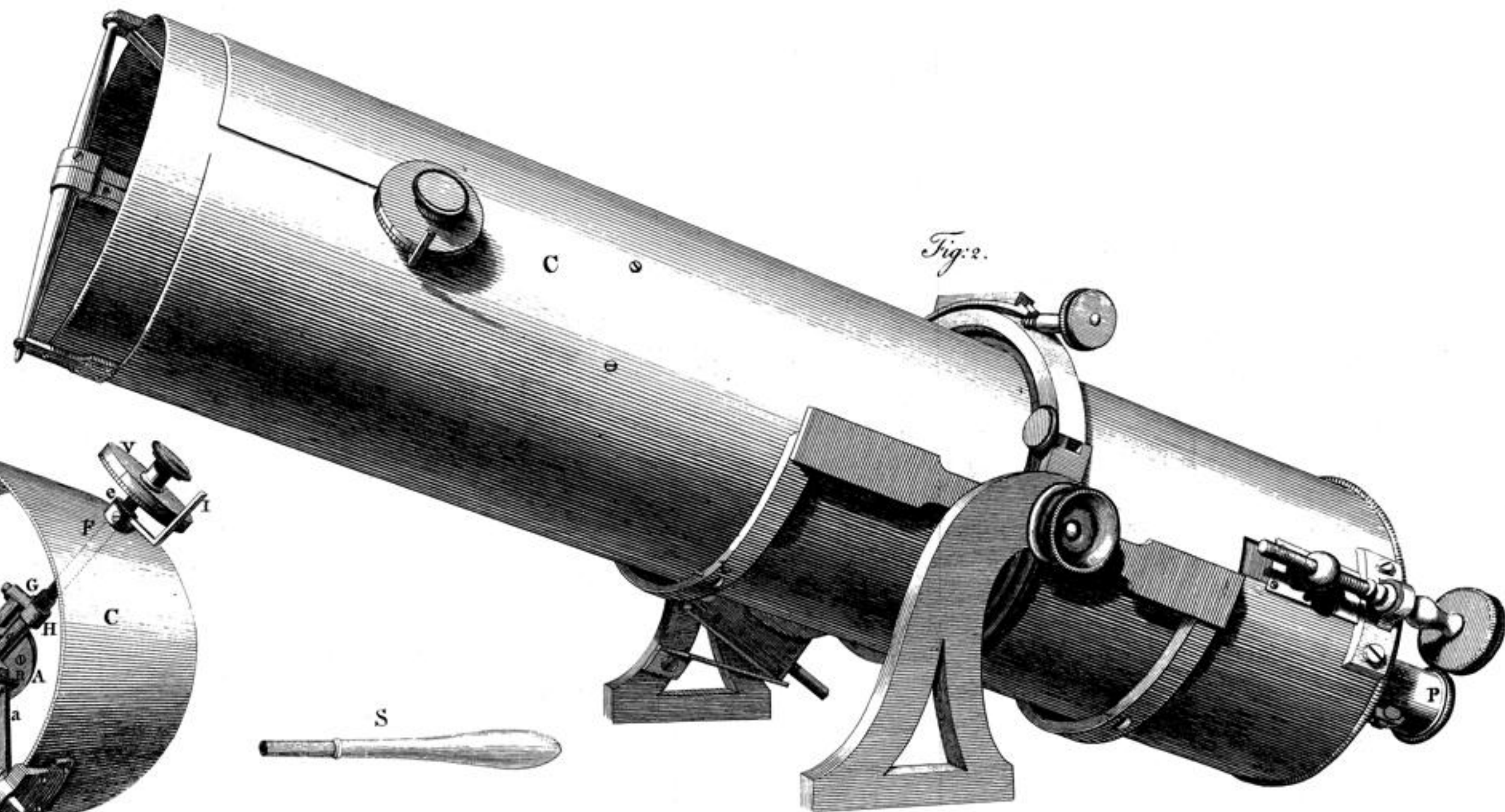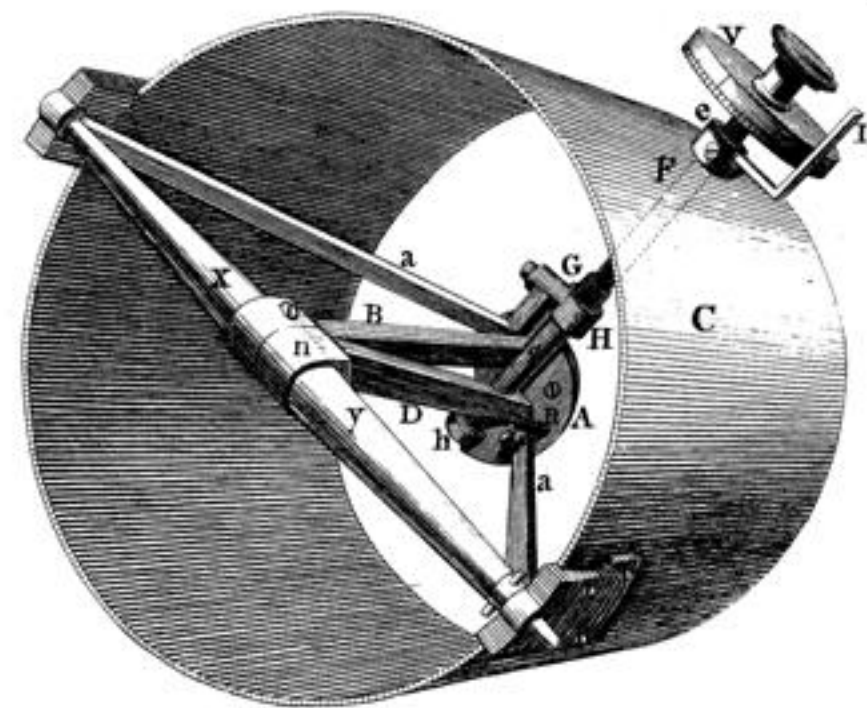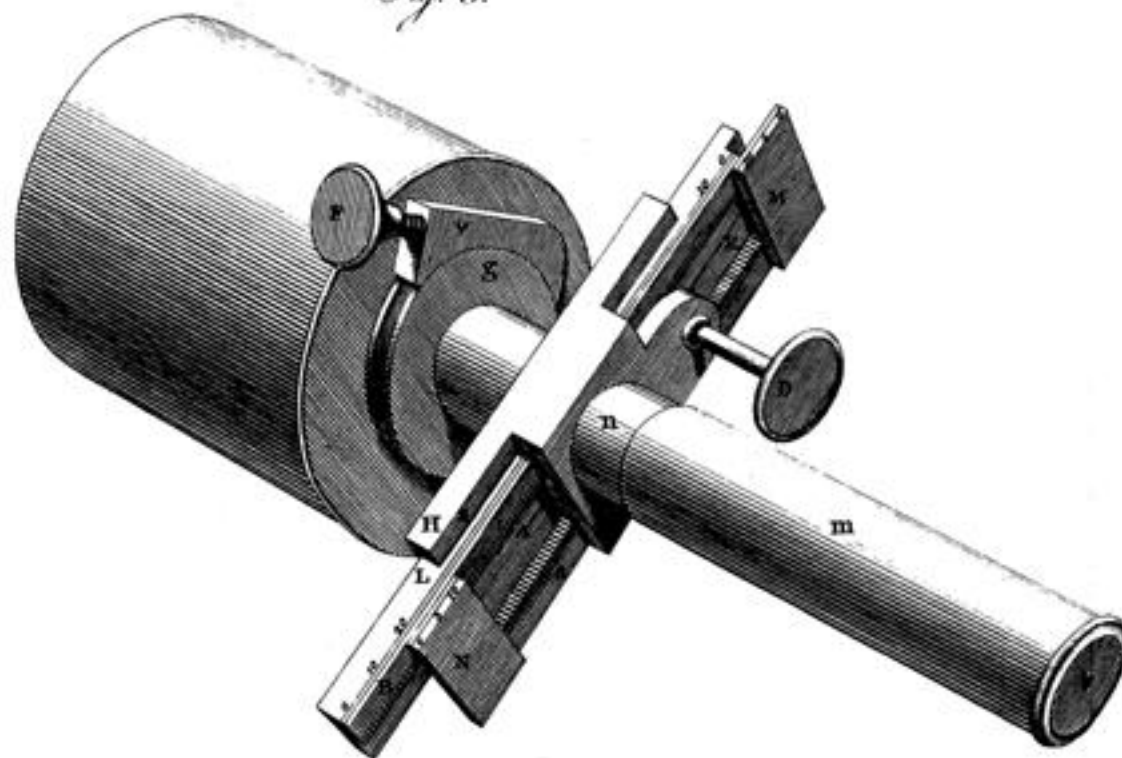
Fig:1.

Fig:2.

Fig: 3.ᵈ

Fig: 4.ᵗʰ